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Analysis of ESCO activities using country indicators

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ABSTRACT

Energy Service Companies (ESCOs) are private-sector instruments that offer energy-/emission-improvement (energy saving, energy efficiency, energy conservation and emission reduction) projects, or renewable-energy projects, in the developed and in some developing countries. There has been an increased interest for the provision of such energy services, driven by a restructuring of the gas and electricity sectors, and the push to mainstream sustainable forms of energy into the market. ESCOs are destined to deliver sustainable-energy solutions, especially in emerging markets. Literature reveals that energy/emission improvements of countries may be related to their innovation- and R&D-activity levels. In this work, we use a literature data on the activities and the sectors targeted by ESCOs in 38 countries, summarized in terms of the age of ESCO market (AEM), number of ESCO companies (NE), and total value of ESCO projects (VE). Along with the Global Innovation Index (GII) data of the countries, we investigate the relationships among the ESCO Indicators (EIs: AEM, NE, VE, sectors targeted by ESCOs), and the Country Indicators (CIs: GII and per-capita GDP, energy consumption, CO_2 emission). We observe noteworthy dependencies between the EIs and CIs. Using the simple trend equations we estimate the missing VEs in the original data. We also project, as a hint for the size and orientation of the upcoming Turkish ESCO market, the set of EIs and the distribution of the sectors that are likely to be targeted by ESCOs in Turkey.

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1. Motivation

ESCOs, as private-sector instruments, guarantee and deliver energy improvements (saving, efficiency, conservation) to their clients. An ESCO's remuneration is tied to the energy improvement actually achieved. ESCOs may finance, or assist in financing, an energy (including renewable-energy and sustainable-energy) project, by providing improvement guarantee.

At the onset of this study, our primary motivation for the analysis of ESCO activities, innovations, energy consumptions, emissions, and GDPs of the countries was to find answers to the following two questions: What is the expected size of the upcoming Turkish ESCO market [1]? What are the sectors that are likely to be targeted by ESCOs in Turkey? Even though the literature was very informative on many points, we could not find direct answers to these questions. Therefore, we got interested in finding answers to the following questions:

- What are the indicators of ESCO activities?
- Are country ESCO activities and targeted sectors GDP related?

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- Are country ESCO activities and targeted sectors innovation related?
- Are country ESCO activities, targeted sectors, energy consumptions, and greenhouse-gas (CO_2) emissions related?

To answer these questions, and to present the overall picture of the above-questioned relationships, we found it suitable to select a single source for the sake of consistency. This source was due to Vine [2], because it involved homogeneous literature data on ESCO activities and the sectors targeted by ESCOs in 38 countries as a result of an identically conducted survey, and it already had the necessary indicators of ESCO activities (age of ESCO market, number of ESCOs, and total value of ESCO projects). With Vine's data, we associated the innovation indexes and the per-capita GDP, energy consumption, and CO_2 emission values of these 38 countries.

We found noteworthy dependencies between the ESCO activity indicators of Vine and the country indicators (innovation index, per-capita GDP, per-capita energy consumption, and per-capita CO_2 emission). We estimated an expected size of the budding Turkish ESCO market in terms of Vine's indicators. We also projected the distribution of the sectors that are likely to be targeted by ESCOs in Turkey.

The organization of this paper is as follows: Section 2 reviews the literature on ESCOs and ends with a brief discussion of the energy–innovation relationships. Section 3 gives the sources and description of our data. In Section 4, we present and analyze the relationships among the ESCO activity indicators, country indicators, and sectors targeted by ESCOs. At the end of this section we also estimate the missing values in Vine's original work and assess the set of ESCO activity indicators for Turkey. Finally, Section 5 summarizes our conclusions.

2. Review of ESCO literature

Interest in energy-efficiency improvements has been great since the first oil-price shock in the early 1970s. Energy end-users going through the first energy crises were looking for significant operation-cost reductions and new ways to manage and monitor their energy consumptions. As a consequence, the ESCO concept was established in the North America at the beginning of 1980s. Recently interest in ESCOs has increased because of the global warming effects of high energy use. ESCOs have strong transition impact as private-sector instruments in delivering energy improvements (saving, efficiency, and conservation). An ESCO guarantees energy improvements to its clients, frequently on a turn-key basis, and ESCO's remuneration is tied to the energy improvements achieved. ESCOs may finance, or assist in arranging financing, for the operation of an energy system by providing a savings guarantee. ESCOs operate under "energy performance contracting" arrangement, implement a project to deliver energy improvement and use the income from the cost savings, or the renewable-energy produced, to repay the costs of the project. The projects can offer turn-key solutions to lower the implementation risks and segregate credit risk from technical and performance risk. For this reason, ESCOs are fundamentally different from consulting firms/engineers, specialized in identification of potential energy improvements, who are typically paid a fee for their advice without undertaking fiasco risks. The interest and co-operation of financial institutions and banks are essential for the development of an ESCO market. Government and donor agencies can stimulate the market for affordable financial options through various means such as soft loans or grants, support of demonstration projects for information dissemination and education programs for financiers.

The financing mechanism of the ESCOs is generally classified as the "guaranteed savings" and "shared savings" [1,3,4]. In the "guaranteed savings" mechanism, the ESCO guarantees a certain level of energy, savings sufficient to cover clients' annual debt obligation [5], and protect the client from any performance risk, and the clients are financed directly by banks or by a financing agency. The client repays the loan and the credit risk stays with the lender. In countries with established banking structure, project financing, and stable economy the "guaranteed savings" mechanism functions properly. Success stories are available for UK, Austria, and Hungary [4]. In "shared savings" mechanism, ESCO carries both the performance and the credit risk. ESCO repays the loan and the credit risk stays with the ESCO; the client assumes no financial risk. In countries with developing ESCO markets, the "shared savings" mechanism is more suitable since it does not require clients to assume investment–repayment risk. The client assumes no financial obligation other than to pay a percentage of the actual savings to the ESCO over a specified period of time. This obligation is not considered debt and does not appear on the customer's balance sheet. In such markets, there are too few ESCOs most of them small-sized. Example World Bank funded stories are available from India, China, and Brazil [2,4].

Literature on ESCOs and ESCO markets is limited but remarkably informative. Vine et al. [6] present financial and cultural barriers and give guidance for the development of an ESCO industry in Japan. Vine et al. [7] overview the evolution of the US ESCO industry. Davies and Chan [8] discuss the benefits, obstacles and necessary ingredients for performance contracting that are likely to be applicable to Hong Kong. Poole and Stoner [9] review the alternative financing models for energy-efficiency performance contracting in Brazil. Bertoldi [10] edits the proceedings of the first European conference on ESCOs. Möllersten and Sandberg [11] investigate the growing market for energy-related collaboration between pulp-and-paper industries and ESCOs in Sweden. Efremov et al. [12] review the ESCO companies in northwest Russia in terms of legal issues and organizational schemes. Goldman et al. [13] analyze the US ESCO-market trends based on a survey of national and regional ESCO firms to assess market activity over the last decade. Their observation for US ESCOs is that performance contracting overcomes market barriers for energy-efficiency investments among large, institutional public-sector customers. Sorrell [14] examine the US and UK markets and concludes that the contribution of ESCOs to low-carbon economy may be smaller than some commentators suggest. Vine [2] presents the results of a survey on ESCO activity in 38 countries outside of the US, and discusses possible actions that countries can take to promote their ESCO industry. Vine states that ESCO-industry associations, financing, measurement and verification protocols, and information and education programs are some of the key mechanisms distinguishing the countries studied. It is concluded that countries putting emphasis on the removal of subsidies, privatization of energy industry and power sector will be among the leaders in developing the ESCO industry. Bertoldi et al. [4] review and analyze the development, current status, and rank ESCO industries in the EU and the new accession countries. They draw attention to major differences in the development of the ESCO markets among various European countries due to different levels of support offered by energy authorities, local market structures and rules, and variation in the definitions, roles and activities of ESCOs. It is argued that energy-efficiency projects offer a cost-effective approach to reducing greenhouse-gas emissions, and the emerging carbon markets will create new opportunities for project financing and the further diffusion of ESCO business. Patlitzianas et al. [15] provide information on the current status of ESCOs' development, in the dimensions of the ESCOs' environment (political–legal, economical–financial, social–cultural and technological), both in EU (Cyprus, France, Greece, Italy, Malta and Spain) and non-EU (Algeria, Egypt, Israel, Jordan, Lebanon, Morocco, Syria, Tunisia and

Turkey) Mediterranean countries. They find that countries (especially the non-EU countries) face several constraints, since the energy efficiency and especially the ESCOs environment is still in a nascent state. Financial barriers are found to be the lack of funds for awareness and the insufficiency of financial support of ESCOs. Bannai et al. [16], using financial derivatives and actual data from existing plants, show how the concepts and tools of financial engineering can be used to hedge the risks due to volatility of fuel and electricity costs to increase the stability of the profit associated with ESCO business. Bertoldi et al. [17] give an update of the status report of ESCOs in Europe to investigate the specific situation in EU-27 and in some non-EU countries. The authors find ESCO markets in Europe to be at diverse stages of development (Germany and Italy: large numbers of ESCOs, Latvia, Romania, and Denmark: a few ESCOs, Albania, Serbia, and Turkey: no ESCOs yet, Hungary: decreasing ESCO market, Estonia, Greece, Belarus, and Macedonia: just getting established, Italy and France: expanding). The authors thus conclude that the field is very turbid and rapidly changing and new information is arising day-by-day. Patlitzianas and Psarras [18] present a decision-support methodology, which also incorporates liberalization and climate change as new parameters, for the formulation of modern energy companies' operational environment in the 13 new and candidate member states of EU. Onaygil and Meylani [19] give an overview of the ESCOs and provide policy suggestions for the forthcoming Turkish ESCO market. Okay et al. [1] present views with regard to the funding and related risks that are likely to be associated with the forthcoming Turkish ESCO market. These views are backed up with Turkish credit and banking market performance and the lessons learned from implementation of some EU-related projects involving the banking sector and small-and-medium-sized enterprises. The roles of the Turkish universities and R&D centers in the implementation of Turkey's Energy Efficiency Law (EEL) and their relationships with the Turkish ESCO market are discussed by Okay et al. [1,20].

A more recent phenomenon is the concept of combining the benefits of performance contracting, under which the majority of ESCOs operate, with the benefits of "green technology", affectionately described as "green performance contracting". Thus, ESCOs are destined to deliver sustainable-energy solutions through performance contracting, especially in emerging markets.

Literature on innovation is vast, yet that on innovation–energy relationships is relatively scarce. Popp et al. [21] review the role of technological change on environmental economics. Based on the significant works cited this review, some of the conclusions in conjunction with the relationships among innovation (technological change), energy efficiency, and energy saving are: (i) the technology is energy saving, (ii) energy patents leads to long-run energy savings, (iii) science and technology (S&T) takeoff should have an energy-saving bias resulting in lower energy prices, however, this leads to more economic growth and greater energy consumption by households, so that the net effect of the S&T takeoff is greater energy use and more emissions, (iv) increase in the price of energy leads to technology adoption that negligibly reduces energy demand, (v) energy prices and regulatory standards affect energy-efficiency-related innovation, and (vi) economic barriers affect adoption of energy-efficiency technology more than financial and uncertainty barriers.

Okay et al. [20] presented Turkey's manufacturing-sector innovation data and analyzed the relationships among sectoral innovations, energy consumptions, and energy-saving potentials. The authors observe that the energy consumptions of the sectors do not change significantly despite varying innovation levels during transitions from economic crisis towards recovery periods.

3. Description of the data

To examine the level of ESCO activity internationally, Vine [2] conducted a survey in late 2002 to collect information on the following key topics for selected countries: (i) the number of ESCOs, (ii) the key sectors targeted by ESCOs, (iii) the four most important barriers facing the ESCO industry, (iv) the approximate value of projects conducted by ESCOs in 2001, and (v) the future of the ESCO industry in that particular country. To answer our questions listed in the motivation section of this work, we found it suitable to select this study of Vine as the single source because of the homogeneity of its data on ESCO activities in 38 countries. Vine's work already had the necessary indicators of ESCO activities as (i) age of ESCO market (**AEM**), (ii) number of ESCOs (**NE**), and (iii) total value of ESCO projects (**VE**). Here, we call AEM, NE, and VE simply as the *ESCO Indicators* (**EIs**). Vine lists the dates at which the first ESCO was established (DFE) as years. We computed the AEM values based on year 2009 as AEM = 2009 − DFE and expressed the VE values in millions USD. In the Vine's original table some entries were given as ranges. We used the upper bounds of the given ranges, except the NE value for the Germany that was used here as 500 even though the given range was 500–1000. Hence, it should be remembered throughout this work that there is an uncertainty in the original data as well. For further discussion of data uncertainties it is strongly recommended that the readers should refer to the original work. In the original table of Vine, the VE values of the 8 countries (Belgium, Bulgaria, Egypt, Hungary, Italy, Lithuania, Mexico, and United Kingdom) were marked as unknown. The full set of EIs was available only for the remaining 30 countries. Turkey was not in the country set of Vine; there were no ESCOs in Turkey in 2002 either. However, as we will present later, we crudely estimated the missing VE values of the 8 countries as well as all missing EIs of Turkey.

With Vine's data, we associated the per-capita GDPs (**GDPpc**), CO_2 emissions (**CO2pc**), and energy consumptions (**ECpc**), as well as the "Global Innovation Index" (**GII**) values, of the 38 countries. Here, we call GDPpc, CO2pc, ECpc, and GII simply as the *Country Indicators* (**CIs**).

The real GDPpc (in 2000 fixed USD) values were obtained from the United States Department of Agriculture Economic Research Service (ERS-USDA) (www.ers.usda.gov/Data/Macroeconomics) based on 17 December 2007 update and, for each country, 1995–2007 averaged values were used. The CO2pc (per-capita metric-ton CO_2 emissions from the consumption and flaring of fossil fuels) values were obtained from the Energy Information Administration (EIA), (www.eia.doe.gov) based on 1 October 2007 update and 1995–2005 averaged values were used. The ECpc values (per-capita total primary energy consumption in millions Btu) were obtained also from the EIA based on 19 December 2008 update and 1995–2005 averaged values were used.

The reasons that we use the GDPpc, CO2pc, and ECpc values as averages over the years 1995–2005/2007 are as follows: first of all, even though Vine states that the survey was conducted in late 2002, we are not sure that EI values are of pointwise significance because we believe that a country's current profile (in terms of EIs and CIs) depends on its historical profile as well; it is a matter of accretion of scientific, technological, and financial know-how. For instance, innovation flourishes as a consequence of knowledge accumulation and R&D experience gained over the years. The ability of compliance with laws and regulations also expedites with experience, and experience is not a pointwise measure. Secondly, in Vine's data, the origins of ESCO markets (DFE) go as far back as 1990–1995, and the average value of AEM is about 15 years. This also fortifies our opinion that it is a matter of accumulation of knowledge and that EI values may not be of pointwise substance. Finally, the GII values were present for the

2006–2007 term. Since it is known that there are strong correlations between GDPs and innovation levels of countries, we use GDPpc values averaged over 1995–2007 to better capture this correlation by extending the averaging period for two more years to approach the years to which the GII data belong. Besides, our general qualitative conclusions were not sensitive to the years selected for the averaging; even though the CIs of the individual countries change over the years, country positions relative to each other do not alter very much.

Innovation is much more than generating new ideas. Translating these ideas into value-adding products and services requires flexibility of attitude and willingness to adapt to, and welcome, unprecedented levels of change on the part of individuals, organizations and society as a whole. Recently, Archibugi et al. [22] review various innovation indicators, discuss their pros and cons, and explore the consistency among indicators. They deduce that most of the country-level rankings are fairly consistent and indicators give quite a faithful and uniform picture on national relative positions in innovative activities, despite a few significant outliers.

As the indicator of innovation intensity of the countries we selected to use the World Business/INSEAD 2006–2007 Global Innovation Index (GII) (www.managementtoday.co.uk/news/625441 or http://elab.insead.edu), primarily because of the presence of GII values for all but two (Cote d'Ivoire and Ghana) of the 38 countries studied by Vine (the 2006–2007 GII scores 107 countries).

The GII was conceived at INSEAD Business School (commissioned by World Business) as a formal model to help show the degree to which individual nations and regions currently respond to the challenge of innovation. This response-readiness is directly linked to a country's ability to adopt and benefit from leading technologies, increased human capacities, organizational and operational developments, and enhanced institutional performance. The framework upon which the GII model rests relies upon eight pillars made up of five inputs and three outputs that underpin the factors that enhance innovative capacity and demonstrate results from successful innovation. The five input pillars which enhance the capacity of a nation to generate ideas and leverage them for innovative products and services are (i) institutions and policies, (ii) human capacity, (iii) infrastructure, (iv) technological sophistication, and (v) business markets and capital. The three output pillars which represent the ultimate benefits of innovation for a nation; more knowledge creation, increased competitiveness and greater wealth generation are (i) knowledge, (ii) competitiveness, and (iii) wealth. Each pillar of the GII model is measured by a number of quantitative and qualitative variables. The averaged scores for the input and output pillars together give an overall score, the GII, which is scaled on a range of 1–7.

As can be understood from the details given above, the content of innovation is very broad and its description and boundaries are fuzzy. Thus, more than a simple ranking measure, we see the GII as a starting point for studying some of the most important questions facing the world economy today. Implementation of an innovation may result in decrease or increase in energy consumption. To the knowledge of the authors, what portion of innovation activities yields favorable results, directly or indirectly, in terms of energy improvements is unknown. We have no information that any standard innovation survey conducted in the world aims to assess the presence of energy-improvement oriented innovation activities in the countries.

Table 1 lists the EI and CI values for the 38 countries studied by Vine, with missing values labeled as "n.a.", and the CIs of Turkey.

4. Analysis of the ESCO and country indicators

Our first analysis was to check if severe colinearity existed in the data using the Principal Component Analysis (PCA) [23]. By removing the countries with missing values (8 countries and Turkey for missing VE values and 2 countries for missing GII values) we formed the data matrix as $\mathbf{X} = [\mathbf{AEM}, \mathbf{NE}, \mathbf{VE}, \mathbf{GDPpc}, \mathbf{CO2pc}, \mathbf{ECpc}, \mathbf{GII}]$ which had 28 rows and 7 columns. We standardized the columns of the data matrix to zero mean and unit variance. The 7 eigenvalues of the 7-by-7 covariance matrix of the data, $\mathbf{X}^T\mathbf{X}$, were computed, which correspond to 55.4, 75.3, 86.9, 93.6, 97.4, 99.2, and 100% of the total variance in the data cumulatively captured by the 7 principal components (PCs). Thus, one needs linear combination of first 5 PCs of the 7-column data matrix to capture 95% of the total variance, and the first PC alone can explain only 55.4% of the variability in the data. These results indicate that the colinearity in the data is not severe. In other words, one cannot strongly state that e.g. only the GDPpc indicator is the common determinant and other columns of the data strongly depend upon it (if this were the case then the first PC alone would have explained more than e.g. 95% of the total variance). The PCA-based colinearity analysis shows us that each of the EI and CI columns are important and the columnwise correlations are not severe.

Next, we present with a sequence of figures the interdependence of the EIs and CIs. Depending on whether missing data exist in the abscissa and/or ordinate variables, the figures contain 28–38 data points corresponding to countries. In order not to crowd the figures we refrained from putting the country codes as data labels. Country code of a particular data point can be deduced from Table 1. In each figure we included the trend-curve, its equation, and regression R^2 value as the indicator of the strength of the relationship. For each figure, we tested only the two-parameter exponential, linear, logarithmic, and power models for the trend-curves, and selected the one with the highest R^2 value. In many cases it was difficult to discriminate the trend models based on R^2 values as they were very close to each other. Since our aim is to present the overall picture of the possible relationships among the EI and CI variables, we did not conduct any detailed regression analysis and we did not check the statistical significance of the models and their parameters.

The top two subplots of Fig. 1 expose the eminent dependencies of CO2pc, and ECpc on GDPpc, and the bottom subplot shows the expected strong link between ECpc and CO2pc. This link between ECpc and CO2pc explains the PCA result that 6 out of 7 PCs can explain 99.2% of the total variance in the data. Fig. 1 proves that these known relationships are valid for the set of countries studied by Vine as well. The dependencies have positive slopes and the GDPpc–ECpc relationship is stronger than that of GDPpc–CO2pc. Ukraine acts as an outlier in both relationships on the high CO2pc and ECpc side of the trend.

Fig. 2 shows the dependencies of the GDPpc, CO2pc, and ECpc on the GII of 36 countries. All dependencies have positive slopes and the strongest relationship is between the GII and GDPpc, as expected. As the countries get richer their innovation levels, per-capita emissions, and energy consumptions increase due to increased industrialization and technological sophistication. If one concentrates on the last 5–9 data points in the high GII region, it seems that there is a leveling-off behavior in CO2pc, and ECpc values. This may be seen as an indicator of satiation in CO2pc and ECpc of the countries with very high GII values (e.g., CA, CH, DE, GB, JP, and SE); increasing innovation and technological sophistication is not increasing their energy consumptions and emissions any further.

Fig. 3 reveals the interdependence of EIs. The relationship between the AEM and NE is very weak; we can conclude that AEM and NE are almost independent EIs. The relationship between the AEM and VE is a bit stronger; we can conclude that there is dependence, though weak, between the maturity of an ESCO market and its value of ESCO projects. This may also be an

Table 1
ESCO and country indicators.

Country and code[a]		ESCO Indicators (EIs)				Country Indicators (CIs)			
		DFE[a]	AEM	NE[a]	VE[a]	GDPpc[b]	CO2pc[c]	ECpc[d]	GII[e]
Argentina	AR	1990	19	5	1	7598	3.53	69.06	2.41
Australia	AU	1990	19	8	25	20,769	18.26	251.61	3.71
Austria	AT	1995	14	25	7	23,633	8.33	173.46	3.64
Belgium	BE	1990	19	4	n.a.	22,153	13.67	254.40	3.77
Brazil	BR	1992	17	60	100	3761	1.89	47.38	2.84
Bulgaria	BG	1995	14	12	n.a.	1791	6.43	113.04	2.12
Canada	CA	1982	27	5	100	23,055	18.18	418.65	4.06
Chile	CL	1996	13	3	0.2	5229	3.61	67.22	3.03
China	CN	1995	14	23	49.7	1094	2.73	34.41	3.21
Columbia	CO	1997	12	3	0.2	6103	1.31	26.56	2.50
Cote d'Ivoire	CI	2000	9	4	0.25	647	0.38	6.95	n.a.
Czech Republic	CZ	1993	16	3	2	5774	11.14	165.59	3.10
Egypt	EG	1996	13	14	n.a.	1462	1.78	29.66	2.24
Estonia	EE	1986	23	20	3	4568	12.63	153.72	3.12
Finland	FI	2000	9	4	1	23,274	10.41	237.69	3.85
Germany	DE	1995	14	500	150	22,944	10.48	175.55	4.89
Ghana	GH	1996	13	3	0.1	263	0.25	6.45	n.a.
Hungary	HU	1990	19	20	n.a.	4831	5.71	105.18	2.88
India	IN	1994	15	8	1	490	0.97	13.21	3.57
Italy	IT	1980	29	20	n.a.	18,547	7.68	131.46	3.48
Japan	JP	1997	12	21	61.7	37,438	9.20	172.23	4.48
Jordan	JO	1994	15	1	2	1765	3.11	45.81	2.61
Kenya	KE	1997	12	2	0.01	398	0.26	4.96	2.22
Korea	KR	1992	17	158	20	11,380	9.28	166.02	3.67
Lithuania	LT	1998	11	3	n.a.	3596	4.01	94.24	2.71
Mexico	MX	1998	11	7	n.a.	5637	3.68	61.33	2.88
Morocco	MA	1990	19	1	0.5	1173	1.04	15.02	2.23
Nepal	NP	2002	7	2	0.25	219	0.10	2.09	1.79
Philippines	PH	1990	19	5	0.2	977	0.86	14.83	2.38
Poland	PL	1995	14	8	30	4411	7.79	97.08	2.53
Slovak Republic	SK	1995	14	10	1.7	4053	7.33	147.57	2.97
South Africa	ZA	1998	11	5	10	3192	8.81	105.28	2.87
Sweden	SE	1978	31	12	30	26,958	6.51	252.81	3.90
Switzerland	CH	1995	14	50	13.5	33,406	6.15	175.11	4.16
Thailand	TH	2000	9	6	6	2178	2.94	44.96	3.01
Tunisia	TN	2000	9	1	0.5	2109	1.99	31.17	2.84
Ukraine	UA	1996	13	5	2.5	765	6.99	124.07	2.24
United Kingdom	GB	1980	29	20	n.a.	24,656	9.49	164.94	4.81
Turkey[f]	TR	n.a.	n.a.	n.a.	n.a.	3132	2.88	46.80	2.75

DFE, date of first ESCO; AEM, age of ESCO market based on 2009; NE, number of ESCOs; VE, total value of ESCO projects in 2001 in millions of USD ($); GDPpc, 1995–2007 averaged per-capita real GDP in 2000 fixed USD; CO2pc, 1995–2005 averaged per-capita metric-ton CO_2 emissions from the consumption and flaring of fossil fuels; ECpc, 1995–2005 averaged per-capita total primary energy consumption in millions Btu; GII, The World Business/INSEAD 2006–2007 Global Innovation Index; n.a., not available.

[a] The original table [2] gives some entries as ranges; here we used the upper bounds of the given ranges except the NE value for DE for which the given range was 500–1000.

[b] ERS-USDA (United States Department of Agriculture Economic Research Service), www.ers.usda.gov/Data/Macroeconomics (based on 17 December 2007 update).

[c] EIA (Energy Information Administration), www.eia.doe.gov (based on 1 October 2007 update).

[d] EIA (based on 19 December 2008 update).

[e] www.managementtoday.co.uk/news/625441 or http://elab.insead.edu.

[f] Not included in the original work of Vine.

indication of the presence/importance of accretion of scientific, technological, and financial know-how in ESCO markets. This observation may further be linked to the innovation issue, since innovation flourishes as a consequence of knowledge accumulation and R&D experience gained over the years. However, it can be seen from Fig. 3 that there are many countries (especially those that are below the trend-curve) with AEMs about one-third of the matured markets, yet they have VEs that are as high as those of the mature markets. The strongest relationship is between the VE and NE. This dependence (the higher the NE the higher the VE) may be an indicator of the fact that the high VEs achieved in these markets are due to the sum of small (low-value) ESCO projects contributed by many ESCOs. This may also indicate that, in general, there is no monopoly in these ESCO markets, and the market is shared by many ESCOs under competition. This deduction seems to be in agreement with the findings of Bertoldi et al. [17]. In their report, the authors provide the following observations for some of the countries: Germany: 5 major ESCOs out of 500, of which about 50 ESCOs are using the "energy-performance-contracting" scheme; France: 3 major ESCOs dominating the market and 100 small ones; Spain: over 10 private companies, a few public ESCOs and a larger number of small ESCO-like companies; Portugal: 7–8 major and many small ESCO-type companies; Ukraine: 3 ESCOs plus a few dozen of national and local ESCO-like consultancies.

Fig. 4 portrays the innovation dependence of the EIs. All dependencies have positive slopes and the strongest relationship is between the GII and VE, followed by NE and AEM. This finding is in accordance with that of GII–GDPpc relationship of Fig. 2; the amount of money that a country can spend on ESCO projects is dependent upon the wealth of that country, which also increases its innovation level.

Fig. 5 depicts the dependence of the EIs on GDPpc. All dependencies have positive slopes and the strongest relationship is between the GDPpc and VE, followed by NE and AEM, as in the case of Fig. 4. The strong GII–GDPpc relationship reveals itself here as well.

Fig. 6 presents the dependence of the EIs on CO2pc emissions. All dependencies have positive slopes and the strongest relationship is between the CO2pc and VE, as in the cases of Figs. 4 and 5, followed by AEM and NE, as oppose to the cases of Figs. 4 and 5.

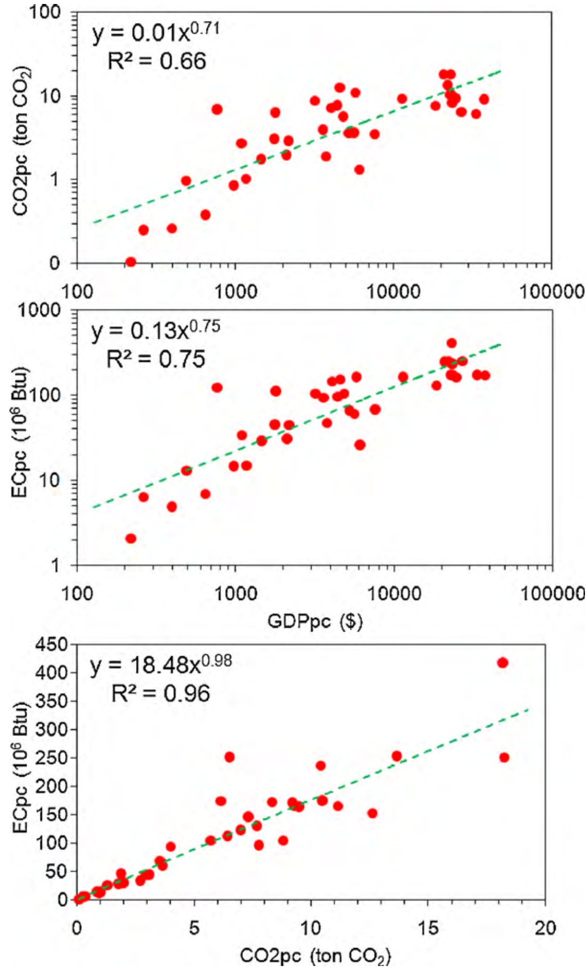


Fig. 1. GDPpc dependence of the CO2pc and ECpc (top two subplots), and ECpc–CO2pc relationship (bottom subplot).

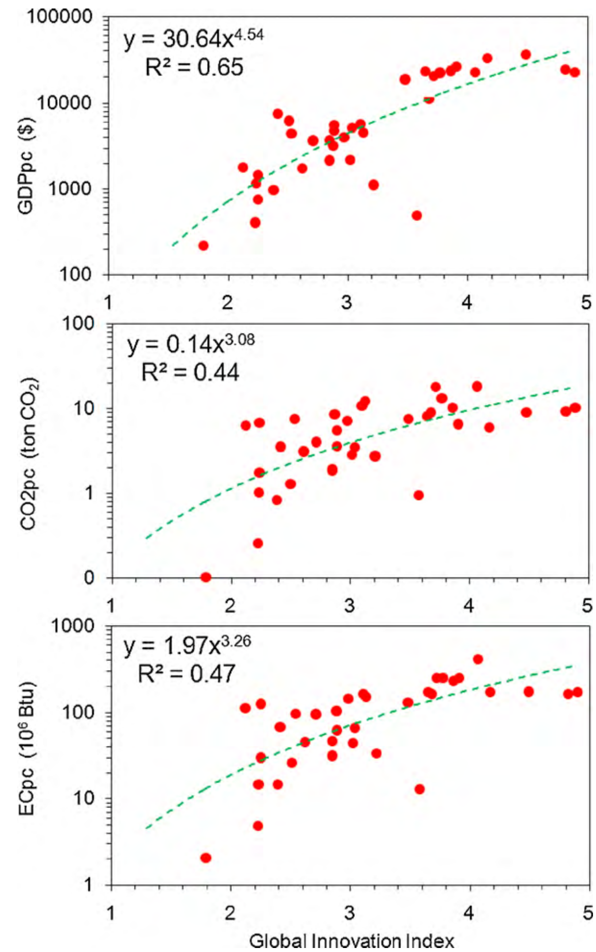


Fig. 2. Innovation dependence of the GDPpc, CO2pc, and ECpc.

Without knowing the detailed nature of the ESCO projects in these countries, this apparent dependence of EIs on CO2pc does not allow us to reach the conclusion that the bulk of the ESCOs are concentrated in emission–reduction projects. Contrary to previous figures, the presence of few outlier countries seems to be more noteworthy; e.g., for the AEM relationship the countries CA, IT, GB, SE; for NE the countries BR, DE, KR; and for VE the countries BR, CN, GH.

Fig. 7 shows the dependence of the EIs on ECpc. All dependencies have positive slopes and the strongest relationship is between the ECpc and VE, as in the cases of Figs. 4–6, followed by AEM and NE, as oppose to the cases of Figs. 4–6. Without knowing the detailed nature of the ESCO projects in these countries, this apparent dependence of EIs on ECpc does not allow us to reach the conclusion that the bulk of the ESCOs are concentrated in energy-improvement projects. The presence of few outlier countries seems to be noteworthy; e.g., for the AEM relationship the countries CA, IT, GB, SE; for NE the countries BR, DE, KR; and for VE the countries BR, CN, DE.

Contrary to Fig. 2, in Figs. 4–7 we do not observe the presence of a satiation behavior in EIs with respect to GII, GDPpc, CO2pc and ECpc, respectively; indicating that there is still a long way to go for the ESCO markets. Due to positive slopes of the trends in Figs. 6 and 7, one can also argue that ESCOs are not very effective in reducing the greenhouse-gas emissions or energy consumptions.

Fig. 8, as bar-chart, shows the full Pearson cross-correlation coefficients of the 7-column data matrix **X**, as sorted from lowest to highest. What we see at first sight is that the correlations among the CIs are the highest ones (between 0.693 and 0.895) and the EIs enter the picture on the relatively lower correlation side (between −0.011 and 0.692). Among the EIs alone, the only strong correlation (0.692) is that of NE–VE pair (Fig. 3). The EI AEM is the one that is least correlated with CIs, except AEM–ECpc: 0.512 (Fig. 7). Highest correlations of EIs are those when they pair with one of the CIs; the GII; VE-GII: 0.582 and NE–GII: 0.520 (Fig. 4). Interestingly, the correlation of GII with these EIs are higher than that of GDPpc; VE–GDPpc: 0.413, and NE–GDPpc: 0.275 (Fig. 5). If compared, it can be seen that the R^2 values of the 21 pairs of regressions given in Figs. 1–7 closely follow the Pearson cross-correlation coefficients of the same pairs of data. These show that innovation is an important country indicator to measure/infer ESCO activities, and this observation may justify the purpose of this work.

In the original article [2], the sectors targeted by ESCOs were also given in a table that lists 33 countries and the corresponding percentages of the 6 sectors classified as: *residential*, *commercial*, *industrial*, *agricultural*, *municipal*, and *other*. Vine indicates that "municipal" references are city-related operations, including railways, and "other" references include street lighting, other government, and public sector that are not classified as "municipal". Fig. A1 is a bar-chart reproduction of Vine's "sectors-targeted" data and can be found in the Electronic Annex in the online version of this article (see Appendix A). Vine states the following observations: (i) many ESCOs did not target the residential sector, (ii) many ESCOs targeted 10–40% of their activity in the commercial sector, (iii) the highest percentage of ESCO activity within a country was in the industrial sector for many countries,

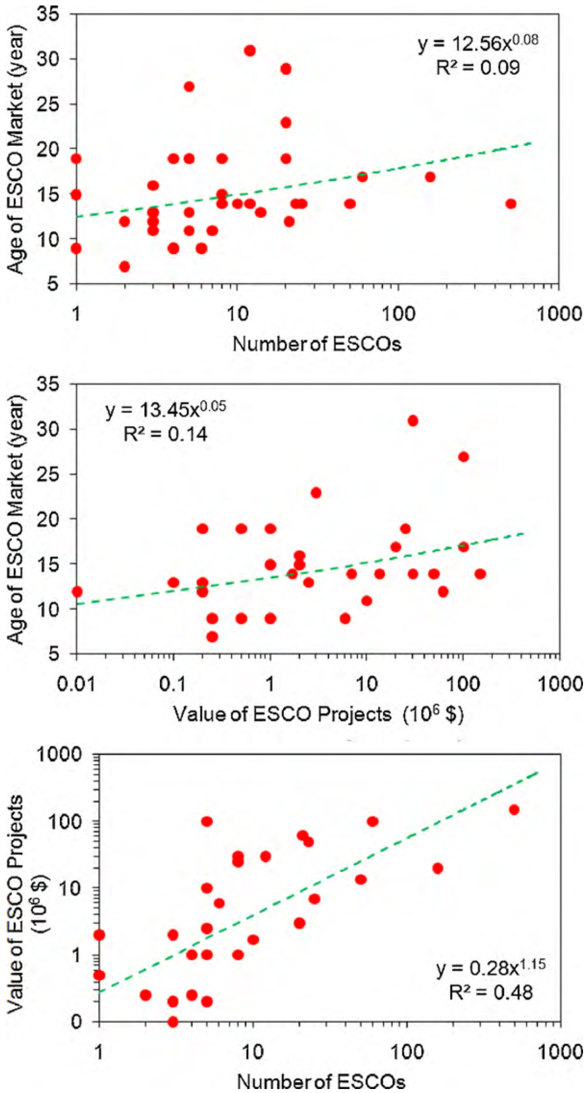


Fig. 3. Interdependence of the ESCO indicators.

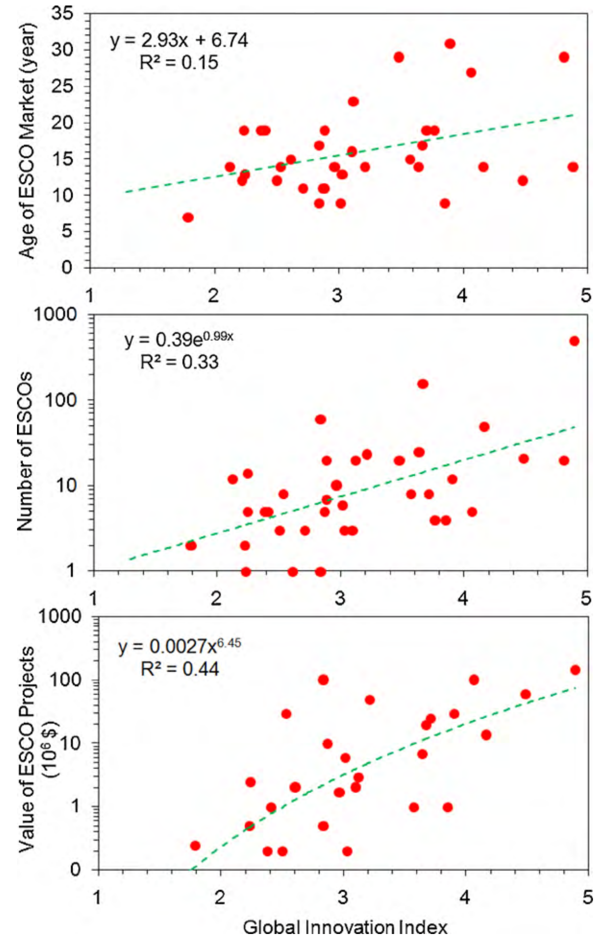


Fig. 4. Innovation dependence of the ESCO indicators.

(iv) ESCOs in several countries targeted the municipal sector, (v) ESCOs in only EE and ZA targeted the agricultural sector, (vi) in only two countries did ESCOs target only one sector: the industrial sector in KE, and the municipal sector in LT, and (vii) in most countries, ESCOs targeted the commercial, industrial, and municipal sectors.

Next, we present with Figs. A2–A8, which can be found in the Electronic Annex in the online version of this article (see Appendix A), the interdependence of the percentage of the sectors targeted by ESCOs (PSTE), EIs, and CIs. Since there are many, we treat the zero values of PSTEs as missing data. Depending on whether missing data exist in the abscissa and/or ordinate variables, the figures contain 3–30 data points corresponding to countries (only 3, 8, 13, 19, 28, and 30 countries out of 33 target the agricultural, other, residential, municipal, commercial, and industrial sectors, respectively). In each figure we included the trend-curve, its equation, and R^2 value as the indicator of the strength of the relationship.

First of all, compared to interdependence of EIs and CIs described via Figs. 1–7, the relationships of the PSTE variables (the sum of PSTE variables of each country is 100%) with EIs and CIs are much weaker in general, as can be seen from the R^2 values given in Figs. A2–A8. Even though the slopes of the trends in Figs. 1–7 were all positive and significant, positive and negative, largely insignificant, slopes are present in Figs. A2–A8.

The percentages of both the residential and industrial sectors targeted by the ESCOs decrease with increasing values of the EI (AEM, NE, VE) and CI (GII, GDPpc, CO2pc, ECpc) variables. These inverse relationships of the residential and industrial sectors with EIs and CIs are stronger and possess much higher R^2 values compared to the rest of the sectors (commercial, municipal, other). From these observations we can conclude that in countries of higher sophistication (higher EI and CI values) with long-established heavy industrialization and higher social welfare, the ESCOs find it more difficult to penetrate residential and industrial sectors. The percentage of the ESCO projects related to industrial process improvements in the developed countries is lower. In our opinion, the reason is that the industrial processes are already energy efficient by design in the countries with matured industrial sectors that have been emphasizing retrofit-design of industrial processes towards energy efficiency by utilizing heat-/power-integration technologies right after the first oil crisis in 1973 [24]. As the technology gets more sophisticated, and as the production processes gets more tightly mass-/heat-/power-/waste-integrated, their energy improvement issues – if there are any left – require significant amount of technology/process know-how, which many ESCOs cannot afford. In such cases, ESCOs are not expected to compete – financially and technically – with highly specialized large process-design companies that can handle any process-related energy-improvement issues, mostly during the process-design stage. Our argument is best supported by the fact that 82% of the ESCO projects are related to lighting and only 2% are

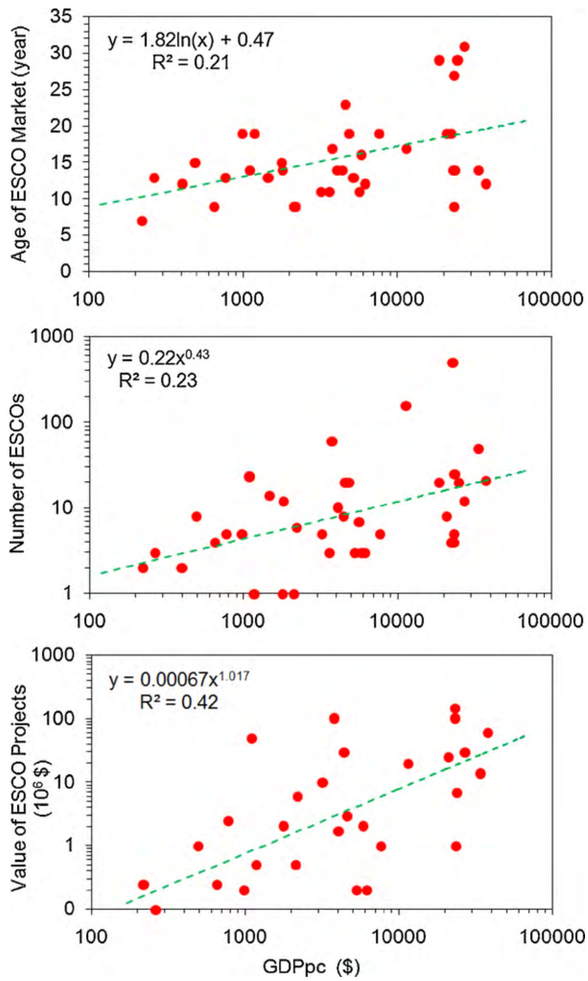


Fig. 5. GDPpc dependence of the ESCO indicators.

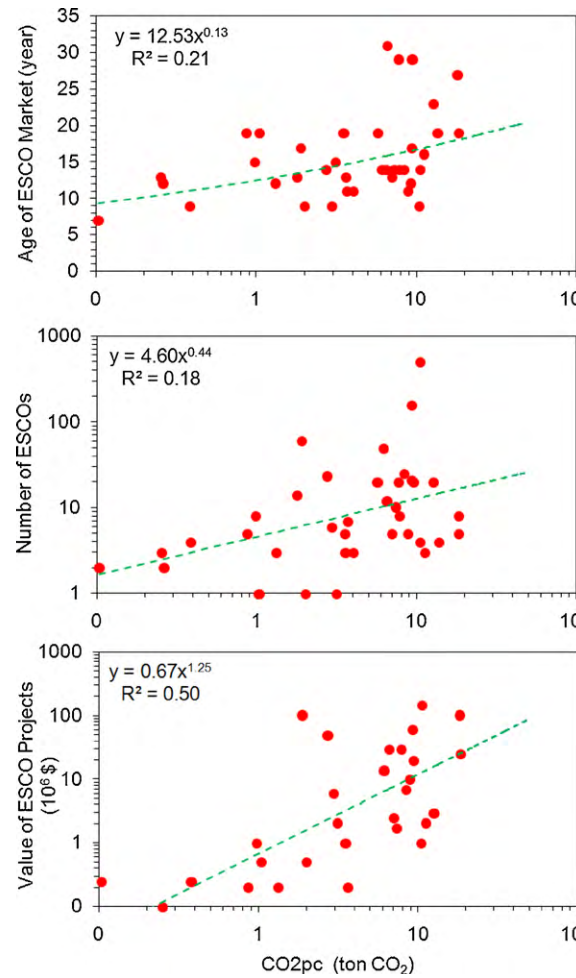


Fig. 6. CO2pc dependence of the ESCO indicators.

related to industrial process improvements in the US [13]. A similar argument may be put forward for the residential sector in the sophisticated countries, where ESCOs may not compete with specialized modern construction firms that can handle residential energy issues during the construction stage.

The relationships of the percentage of both the commercial and municipal sectors targeted by ESCOs with the EI and CI variables are more complex. The figures exhibit, very weakly, both positive (e.g., GDPpc, ECpc) and negative slopes (e.g., NE) in the trends, however, R^2 values are among the lowest ones (in the range 0.01–0.08). Probably, one cannot reject the null hypothesis that the slopes are effectively zero, indicating unrelatedness. Thus, for these two sectors it would not be wise to draw strong conclusions for their EI and CI dependencies. However, our conclusion from the discussion of Fig. 3 was that the relationship between VE and NE was very strong with positive slope and this dependence (the higher the NE the higher the VE) might be an indicator of the fact that the high VEs achieved in these markets were probably due to the sum of small (low-value) ESCO projects contributed by many ESCOs sharing the market under competition. Most probably, the commercial sectors in many of these countries are mainly occupied by small-and-medium-sized enterprises (SMEs) of dissimilar business areas that are interested in quite diverse areas of small-to-medium-scale energy-improvement issues that can be undertaken by small-to-medium-sized ESCOs. The same proposition may be valid for the small-and-medium-sized municipalities as well. These diverse and small-scale ESCO projects may be an explanation for the apparent unrelatedness of the percentage of the commercial and municipal sectors targeted by ESCOs to EIs and CIs.

The relationship of the percentage of the "other" sector targeted by ESCOs with the EI and CI variables is also multifaceted. The sector classified as "other" includes street lighting, other government and public sector jobs that are not classified as "municipal". The figures exhibit weak positive (AEM, CO2pc, GDPpc, ECpc) and negative slopes (GII) as well as relatively strong negative slopes (VE, NE) in the trends. Argentina (AR), with 60% targeted value, acts as an outlier in these figures and decreases the reliability of the trend-curves in some cases. Apparently, the trends that would be least affected by the removal of AR from the figures belong to NE, ECpc, CO2pc, and GDPpc variables. The removal of AR will probably make the other trends insignificant, indicating unrelatedness of the corresponding variables to the percentage of the "other" sector targeted by ESCOs. Negative slope with respect to NE may be an indication of the presence of only few large ESCOs that can undertake large street-lighting projects. Positive slope with respect to ECpc may also be an indication of the significance of the lighting-related projects in the "other" sector.

Fig. 9 is a sorted bar-chart representation of the cross-correlation coefficients of the data matrix **X** augmented with the 5 PSTE variables including the zero values. The agricultural sector was not included as it is targeted by ESCOs only in 3 countries. Due to inclusion of the zero values, which show the absence of those sectors targeted by ESCOs, the cross-correlations may be more

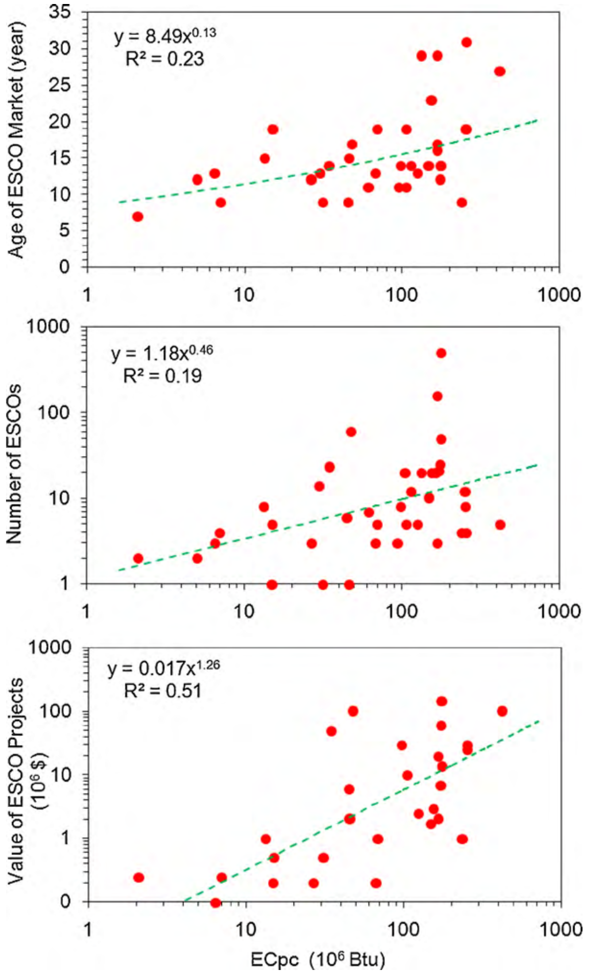


Fig. 7. ECpc dependence of the ESCO indicators.

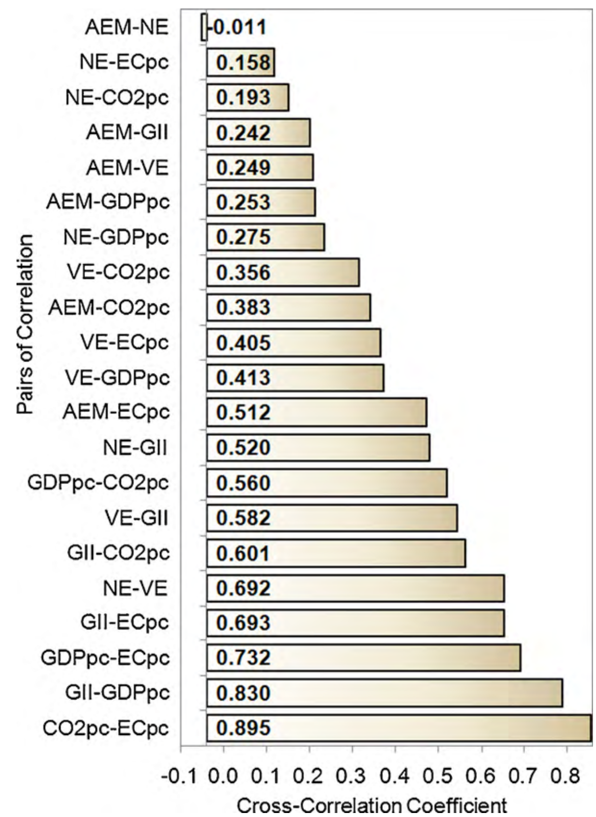


Fig. 8. Sorted cross-correlation coefficients of the data-matrix columns.

informative. Fig. 9 shows only the correlations of the PSTE variables among themselves and with the EI and CI variables. The correlations among the EIs and CIs are as given by Fig. 8. Compared to Fig. 8 which shows the cross-correlations between the EIs and CIs (all positive with one exception), Fig. 9 shows both negative and positive correlations. We subjectively divided the range of correlations into five zones indicated by the dashed lines. The middle zone is the widest one and contains very weak positive and negative correlations, indicating almost unrelatedness of the 16 pairs of PSTEs (mostly residential), EIs, and CIs. It is interesting to notice that in this zone most of the correlation pairs (low in absolute values) are those of the PSTE variables with EIs. Highest positive correlations belong to the pairings of the commercial and municipal sectors mostly with the CIs, but the topmost correlation is between the commercial and VE (though the correlation value 0.33 is far from unity). This zone shows that as the countries get richer (higher GDPpc and GII), ESCOs find more opportunities in the commercial and municipal sectors. The VE, CO2pc, ECpc, GDPpc, and GII are significant (favorable) indicators for the commercial and municipal targets in the developed countries, but unfavorable indicators for the developing ones. Highest negative correlations belong to the pairings of the industrial and commercial sectors mostly with the CIs. The topmost inverse correlation is between the commercial and the "other" sector (though the inverse correlation value −0.58 is far from −1), indicating trade-off between these two sectors as the countries get richer. This zone shows that as the countries get richer (higher GDPpc and GII), ESCOs find less opportunities in the industrial sector. The ECpc, CO2pc, GDPpc, GII, and AEM are significant unfavorable indicators for the industrial targets in the developed countries, but favorable indicators for the developing ones. Medium inverse correlations (second zone from the top) are within the PSTE variables. It seems that the inversely correlated sector pairs: industrial–municipal, commercial–industrial, residential–industrial/–commercial, and municipal–other are complementary to each other.

Finally, returning back to our motivation for the analysis of ESCO activities, innovations, energy consumptions, emissions, and GDPs of countries, at the end of this section we estimate the missing values in the Vine's original work and assess the expected size of the upcoming Turkish ESCO market in terms of EIs. Currently, there are few ESCOs in Turkey (their project-financing mechanisms are not clear yet). However, EEL regulations, particularly for the industrial sector, were already being practiced since 1995. There are several private Turkish energy companies that do energy efficiency and related business with diverse sectors such as pharmaceuticals, chemicals, automotive, agriculture, paint, food and beverages, airports, hospitals, buildings. Among them some are involved in co-/tri-generation, automation, power quality and reliability, equipment efficiency, demand management, and lighting projects. These energy companies are acquainted with outsource financing, energy accounting, energy-price risk management, energy auditing, budgeting, training and consulting for energy managers, energy monitoring and reporting, and financing tools. They conceive to finance energy projects with the help of EU and World Bank funds in the short run and with Turkish banks' credits in the medium to long run.

In the original table of Vine, the VE values of the 8 countries (Belgium, Bulgaria, Egypt, Hungary, Italy, Lithuania, Mexico, United Kingdom) were marked as unknown. We estimate these missing values using the trend equations for the relationships VE–NE, VE–GII, VE–GDPpc, VE–CO2pc, and VE–ECpc that were given in Figs. 3–7, respectively. Table 2 lists these estimated VE values of

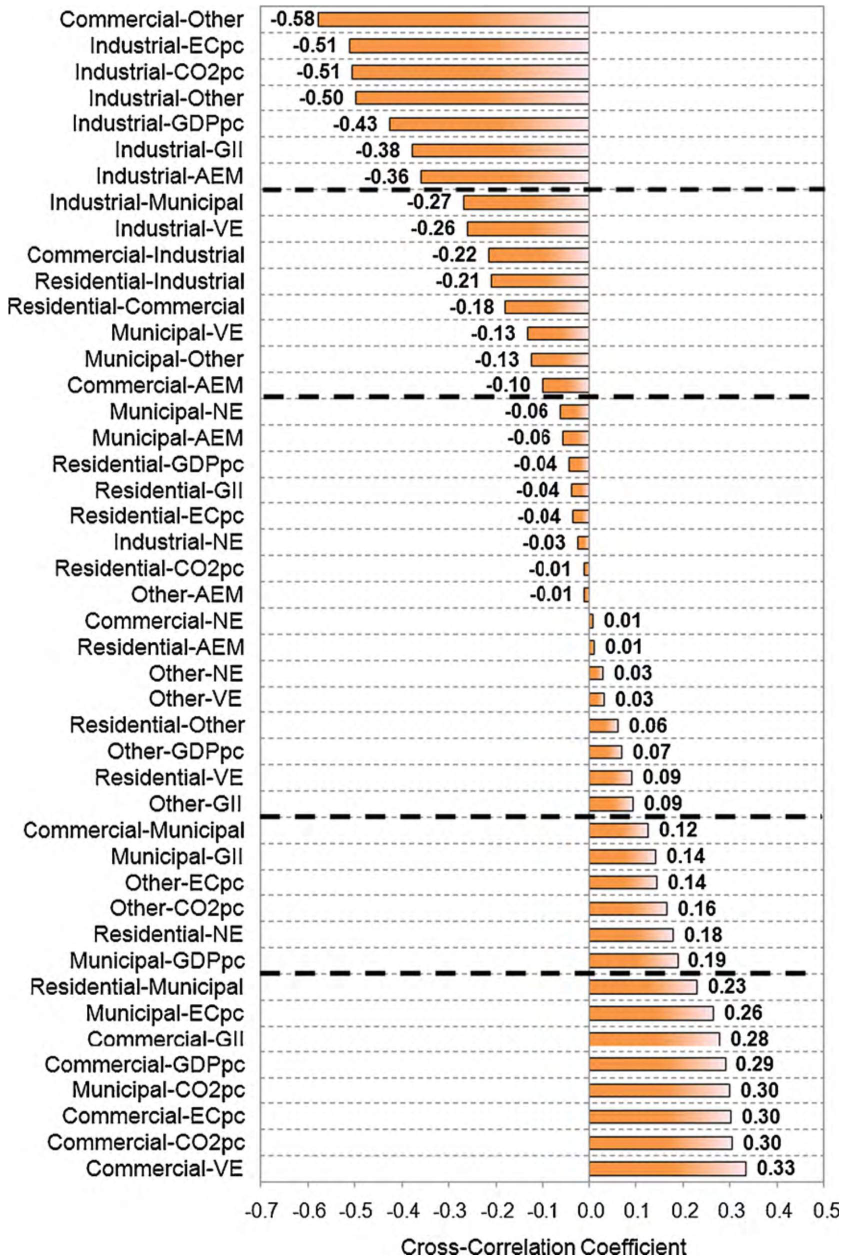


Fig. 9. Sorted cross-correlation coefficients between the percentage of the sectors targeted by ESCOs, ESCO indicators, and country indicators.

the 8 countries. Their R^2-weighted average values may be used in place of the missing values, with some confidence.

Turkey was not included in the original work of Vine; at that time there were no ESCOs in Turkey. We estimate the yet unknown values of the EIs of Turkey using the trend equations of the GII, GDPpc, CO2pc, and ECpc dependencies of the EI variables AEM, NE, and VE that were given in Figs. 4–7, respectively. Table 3 lists these estimated EIs of Turkey. With some confidence, we assess the expected size of the upcoming Turkish ESCO market as AEM = 14, NE = 7, and VE = 2.5. According to these estimates, Turkey should have started its ESCO market 14 years ago (since 1995). It is interesting to note that much before the EEL of Turkey (2007), part

Table 2
Estimated values of ESCO projects.

Trend-curve used in estimation	Estimated VE values for the countries (10^6 \$)							
	BE	BG	EG	HU	IT	LT	MX	GB
VE–NE in Fig. 3, $R^2 = 0.48$	1.4	4.9	5.8	8.8	8.8	1.0	2.6	8.8
VE–GII in Fig. 4, $R^2 = 0.44$	14.1	0.3	0.5	2.5	8.4	1.7	2.5	67.8
VE–GDPpc in Fig. 5, $R^2 = 0.42$	17.6	1.4	1.1	3.7	14.7	2.8	4.4	19.6
VE–CO2pc in Fig. 6, $R^2 = 0.50$	17.6	6.9	1.4	5.9	8.6	3.8	3.4	11.2
VE–ECpc in Fig. 7, $R^2 = 0.51$	18.3	6.6	1.2	6.0	7.9	5.2	3.0	10.6
R^2-weighted average values	13.8	4.2	2.0	5.5	9.5	3.0	3.2	22.7

Table 3
Estimated values of ESCO indicators for Turkey.

Trend-curve used in estimation	Estimated ESCO indicators		
	AEM (year)	NE	VE (10^6 $)
GII-based, Fig. 4	15	6	1.8
GDPpc-based, Fig. 5	15	7	2.4
CO2pc-based, Fig. 6	14	7	2.5
ECpc-based, Fig. 7	14	7	2.2

of its regulations, particularly for the industrial sector, were already being practiced since 1995 by several (5–10) private Turkish energy companies. In the opinion of the authors, the value of the ESCO projects estimated as 2.5 million USD is exceedingly conservative when compared with the VE values of other developing countries such as Brazil (100), Bulgaria (4.2), Czech Republic (2), Egypt (2), Estonia (3), Hungary (5.5), Jordan (2), Lithuania (3), Mexico (3.2), Poland (30), Slovak Republic (1.7), and Ukraine (2.5).

We also estimate the yet unknown values of the "percentage of sectors that are likely to be targeted by ESCOs" (except the agricultural sector) in Turkey from the trend equations given in Figs. A2–A8, using the actual values of the GII, GDPpc, CO2pc, ECpc, and the estimated values of AEM, NE, VE. Since the sum of the estimated values is not necessarily 100%, we normalized these values such that the sum of the percentages of the sectors targeted gives 100%. Then, since the R^2 values greatly vary between 0.011 and 0.678, we computed the R^2-weighted average values as the expected values of the estimated PSTEs. Table 4 lists the "agricultural-sector-free" estimated and normalized PSTE values for Turkey. Thus, we assess the expected distribution of the sectors that are likely to be targeted by the upcoming Turkish ESCO market as residential: 9%, commercial: 22%, industrial: 32%, municipal: 20%, and other: 17%. These estimates, according to our previous discussions, put Turkey in the developing-countries league, especially due to relatively high estimated percentage value of the industrial sector targeted. In Turkey, as of July 2009, there are 5 ESCOs approved by the EIE (www.eie.gov.tr); 3 of which are certified for both industrial and residential projects, 1 is certified for the industrial projects and the other 1 for the residential projects. In Table 4, if the percentages of the commercial and industrial sectors are lumped together as "industrial" (54%), and if the municipal, other, and residential sectors are lumped together as "residential" (46%), it is seen that the current number of ESCOs and their distribution of sector targets (50% "industrial", 50% "residential") are in accordance with our estimation.

Table 4
Estimated percentages of the sectors that are likely to be targeted by ESCOs in Turkey.

Trend-curve used in estimation	Estimated distribution of sectors to be targeted (%)				
	Residential	Commercial	Industrial	Municipal	Other
GII-based, Fig. A2	8	20	29	25	18
GDPpc-based, Fig. A3	10	25	35	21	9
CO2pc-based, Fig. A4	9	21	31	31	8
ECpc-based, Fig. A5	10	25	39	18	8
AEM-based, Fig. A6	9	24	33	23	11
NE-based, Fig. A7	7	17	27	24	25
VE-based, Fig. A8	10	21	30	19	20
R^2-weighted averages	9	22	32	20	17

5. Conclusions

In this work, we used the data compiled by Vine [2] as a result of a survey conducted in 2002 in order to examine the level of international ESCO activity. The data summarized the ESCO activities in 38 countries in terms of the age of ESCO market (AEM), number of ESCO companies (NE), total value of ESCO projects (VE), and the percentage of the sectors targeted by ESCOs (PSTE). We called these as the *ESCO Indicators* (EIs). With Vine's data, we associated the countries per-capita GDPs (GDPpc), energy consumptions (ECpc), and CO_2 emissions (CO2pc) as well as the World Business/INSEAD Global Innovation Index (GII). We called these as the *Country Indicators* (CIs). We observed notable relationships among EIs and CIs. Using the simple trend equations we estimated the missing VEs in the Vine's work. We also assessed the size and orientation of the upcoming Turkish ESCO market by estimating, via the known CIs, the set of EIs and the distribution of the sectors that are likely to be targeted by ESCOs in Turkey. The followings are our major conclusions obtained from the analysis of the data.

The amount of money a country can spend on ESCO projects is dependent upon the wealth (innovation level) of that country. Interestingly, the correlation of GII with the EIs is higher than that of GDPpc (VE–GDPpc and NE–GDPpc). This shows that GII is an important CI to infer ESCO activities. The leveling-off behavior in CO2pc–GII and ECpc–GII dependencies indicate that countries with high GIIs are not increasing their energy consumptions and emissions any further.

AEM–NE relationship is very weak, indicating that these EIs are almost independent. AEM–VE relationship is a bit stronger, pointing to the weak dependence between the maturity of an ESCO market and its VE. This indicates the importance of accretion of scientific, technological, and financial know-how (innovation potential) in ESCO markets.

The VE–NE relationship indicates that the high VEs achieved in the markets are due to the sum of small (low-value) ESCO projects contributed by many ESCOs, as also observed by Bertoldi et al. [17]; implying that the ESCO markets are competitive. Diverse and small-scale ESCO projects may be an explanation for the apparent unrelatedness of the percentage of the commercial and municipal sectors targeted by ESCOs to EIs and CIs.

The percentages of the residential and industrial sectors targeted by ESCOs decrease with increasing EIs and CIs. These inverse relationships are stronger compared to the rest of the sectors (commercial, municipal, other). These observations imply that in countries of higher sophistication (high EIs and CIs) with long-established heavy industrialization and higher social welfare, the ESCOs find it more difficult to penetrate the residential and industrial sectors. In general, the percentage of the ESCO projects related to industrial process improvements in the developed countries is lower, fortifying our opinion that the industrial processes are already energy efficient by design in the countries with matured industrial sectors. As the technology gets more sophisticated, and as the production processes gets more tightly mass-/heat-/power-/waste-integrated, their energy-improvement issues require significant amount of technology/process know-how, which many ESCOs cannot afford. With a similar argument, ESCOs may not compete with specialized modern construction firms that can handle residential energy issues during the construction stage.

In richer countries ESCOs find more opportunities in the commercial and municipal sectors. The high levels of VE, CO2pc, ECpc, GDPpc, and GII are favorable indicators for the commercial and municipal targets in the developed countries, but unfavorable

indicators for the developing ones. In richer countries ESCOs find fewer opportunities in the industrial sector. The high levels of ECpc, CO2pc, GDPpc, GII, and AEM are unfavorable indicators for the industrial targets in the developed countries, but favorable indicators for the developing ones. It seems that the inversely correlated sector pairs: industrial–municipal, commercial–industrial, residential–industrial/–commercial, and municipal–other are complementary to each other.

The positive slopes of the EI–CO2pc and EI–ECpc dependencies may be an indication of either the ineffectiveness of ESCOs or the unsaturatedness of ESCO markets in most of the countries. However, mostly negative slopes of the dependencies of PSTE variables on EIs and CIs may be an evidence of unsaturatedness of ESCO markets, thus relieving the doubts on ineffectiveness of ESCOs. It seems that in the developing countries ESCO activities in wide variety of sectors are far from a satiation point. Thus, there may be still a long way to go for the ESCO markets, if ESCOs involve in and capitalize on innovations. Yet, in the developed countries, especially large-scale industrial projects seem to be unfavorable for small-and-medium-size ESCOs.

We hope that the relationships between the ESCO activities and country indicators delineated in this work will be helpful in inferring the role of ESCOs in country-specific implementation of renewable- and/or sustainable-energy projects, especially in emerging markets.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.rser.2010.07.013.

References

[1] Okay E, Okay N, Konukman AES, Akman U. Views on Turkey's impending ESCO market: is it promising? Energy Policy 2008;36:1821–5.
[2] Vine E. An international survey of the energy service company (ESCO) industry. Energy Policy 2005;33:691–704.
[3] Bertoldi P, Rezessy S. Energy service companies in Europe. Status report 2005. Ispra, Italy: European Commission DG Joint Research Center; 2005. www.managenergy.net/products/R1742.htm.
[4] Bertoldi P, Rezessy S, Vine E. Energy service companies in European countries: current status and a strategy to foster their development. Energy Policy 2006;34:1818–32.
[5] Goldman C. Overview of U.S. ESCO industry: recent trends and historic performance. In: International workshop on energy efficiency services industries; 2003.p. 1–33.
[6] Vine EL, Murakoshi C, Nakagami H. International ESCO business opportunities and challenges: a Japanese case study. Energy 1998;23:439–47.
[7] Vine E, Nakagami H, Murakoshi C. The evolution of the US energy service company (ESCO) industry: from ESCO to super ESCO. Energy 1999;24:479–92.
[8] Davies HA, Chan EKS. Experience of energy performance contracting in Hong Kong. Facilities 2001;19:261–8.
[9] Poole AD, Stoner TH. Alternative financing models for energy efficiency performance contracting. In: Workshop: "developing the business of energy efficiency performance contracting"; 2003, http://3countryee.org/PerformContract/.
[10] Bertoldi P, editor. Proceedings of the 1st European conference on energy service companies (ESCOs): creating the market for the ESCOs industry in Europe. Milan (Italy): European Commission Joint Research Centre, Institute Environment and Sustainability; 2003 [Report No.: EUR 20761 EN]http://re.jrc.ec.europa.eu/energyefficiency/events/esco_conf.htm.
[11] Möllersten K, Sandberg P. Collaborative energy partnerships in relation to development of core business focus and competence—a study of Swedish pulp and paper companies and energy service companies. Business Strategy and the Environment 2004;13:78–95.
[12] Efremov D, Smirnyagin D, Valerianova O, Hernesniemi H. ESCO companies in northwest Russia legal issues and organizational schemes. The Research Institute of the Finnish Economy. Discussion Paper No. 912; 2004. http://ideas.repec.org/p/rif/dpaper/912.html.
[13] Goldman CA, Hopper NC, Osborn JG. Review of US ESCO industry market trends: an empirical analysis of project data. Energy Policy 2005;33:387–405.
[14] Sorrell S. The contribution of energy service contracting to a low carbon economy. Tyndall Centre technical report no. 37; 2005. www.tyndall.ac.uk/research/theme2/final_reports/t3_21.pdf.
[15] Patlitzianas KD, Doukas H, Psarras J. Designing an appropriate ESCOs' environment in the Mediterranean. Management of Environmental Quality An International Journal 2006;17:538–54.
[16] Bannai A, Tomita Y, Ishida Y, Miyazaki D, Akisawa A, Kashiwagi T. Risk hedging against the fuel price fluctuation in energy service business. Energy 2007;32:2051–60.
[17] Bertoldi P, Boza-Kiss B, Rezessy S. Latest development of energy service companies across Europe—a European ESCO update. European Commission Joint Research Centre, Institute Environment and Sustainability; 2007[Report No.: EUR 22927 EN]www.energy.eu/publications/LBNA22927ENC_002.pdf.
[18] Patlitzianas KD, Psarras J. Formulating a modern energy companies' environment in the EU accession member states through a decision support methodology. Energy Policy 2007;35:2231–8.
[19] Onaygil S, Meylani EA. Energy efficiency consulting companies—an overview of the current situation in the world (in Turkish). In: Energy efficiency congress; 2007.p. 41–54.
[20] Okay N, Konukman AES, Akman U. Analysis of innovation and energy profiles in the Turkish manufacturing sector. Working paper, MPRA – Munich Personal RePEc Archive, Item ID: 16779; 2009. http://mpra.ub.uni-muenchen.de/16779/.
[21] Popp D, Newell RG, Jaffe AB. Energy, the environment, and technological change. National Bureau of Economic Research (NBER); 2009[p. 1–74, Working paper 14832]http://www.nber.org/papers/w14832.
[22] Archibugi D, Denni M, Filippetti A. The technological capabilities of nations: the state of the art of synthetic indicators. Technological Forecasting and Social Change 2009;76:917–31.
[23] Johnson RA, Wichern DW.In: Applied multivariate statistical analysis5th ed., New Jersey: Prentice-Hall Inc.; 2002.
[24] Furman KC, Sahinidis NV. A critical review and annotated bibliography for heat exchanger network synthesis in the 20th century. Industrial and Engineering Chemistry Research 2002;41:2335–70.

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